Global Environmental Change xxx (2011) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Informing adaptation responses to climate change through theories of transformation

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ARTICLE INFO

Article history:
Received 27 January 2011
Received in revised form 3 October 2011
Accepted 8 October 2011
Available online xxx

Keywords:
Transition management
Decision-making
Resilience
Adaptive capacity
Adaptation Action Cycles

ABSTRACT

Transformative actions are increasingly being required to address changes in climate. As an aid to understanding and supporting informed decision-making regarding transformative change, we draw on theories from both the resilience and vulnerability literature to produce the Adaptation Action Cycles concept and applied framework. The resulting Adaptation Action Cycles provides a novel conceptualisation of incremental and transformative adaptation as a continuous process depicted by two concentric and distinct, yet linked, action learning cycles. Each cycle represents four stages in the decision-making process, which are considered to be undertaken over relatively short timeframes. The concept is translated into an applied framework by adopting a contextual, actor-focused suite of questions at each of the four stages. This approach compliments existing theories of transition and transformation by operationalising assessments at the individual and enterprise level. Empirical validation of the concept was conducted by collaborating with members of the Australian wine industry to assess their decisions and actions taken in response to climate change. The contiguous stages represented in the Adaptation Action Cycles aptly reflected the diverse range of decision-making and action pathways taken in recent years by those interviewed. Results suggest that incremental adaptation decision-making processes have distinct characteristics, compared with those used in transformative adaptation. We provide empirical data to support past propositions suggesting dependent relationships operate between incremental and transformative scales of adaptation.

1. Introduction

Adaptive capacity greatly influences the vulnerability status of communities and regions to climate change (Adger et al., 2005; Adger, 2006). Capacity to adapt includes not only the preconditions necessary to enable adaptation, including social and physical elements, but also the ability to mobilise them (Nelson et al., 2007) (see Smit and Wandel, 2006 for a review of adaptive capacity and related concepts). These may, in part, be facilitated by enhancing the interaction between science, policy and practice (Smithers and Smit, 1997; Österblom et al., 2010). It may be argued therefore that the present trend for an increasing amount of research and development (R&D) resources to be focused on delivering adaptation options for agricultural, fisheries and forestry production (Fig. 1), along with increasing R&D expenditure, offers the potential for society to realise a corresponding increase in its capacity to adapt to climate change.

Nelson et al. (2007) suggest that one approach for adapting to climate change and reducing vulnerability is by placing emphasis on the individuals or 'actors' who directly respond to specific environmental stimuli. Indeed, adaptation includes not only the set of actions undertaken to maintain the capacity to deal with current or future predicted change, it also relates to the decision-making process associated with change management itself. The vast majority of proposed adaptation response strategies described in the agricultural production literature, however, aim to inform only the short-term tactical decisions for incremental change (e.g. Stokes and Howden, 2010). Such strategies can be categorised as either reducing sensitivity, altering exposure or increasing resilience to cope with change (Adger et al., 2005). Yet, with few signs of the dramatic cuts in greenhouse gas emissions needed

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doi:10.1016/j.gloenvcha.2011.10.003

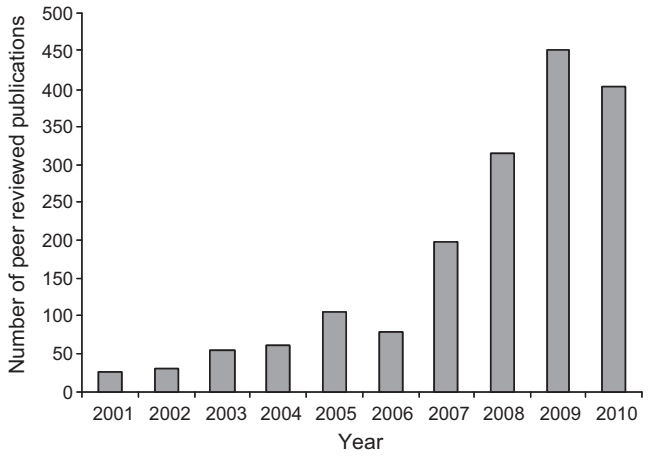

Fig. 1. Increasing trend in the number of peer-reviewed publications relating to climate change adaptation in the area of agriculture, fisheries and forestry over the past 10 years. String used: Topic = ("climate change") AND Topic = (adaptation) AND Topic = (agricult* OR fisher* OR forest*) AND Year Published = (2000–2010). Databases used: Web of Science®, CABI, Zoological Record®, Journal Citation Reports®, MEDLINE®, Current Contents Connect®, Derwent Innovations Index℠.

to reduce anthropogenic temperature increases to within 2 °C of 1990 levels occurring (Hare and Meinshausen, 2006), it is unlikely that incremental change alone will be sufficient to enable some agricultural production systems to operate within thresholds of sensitivity, exposure and adaptive capacity (Howden et al., 2007; Stafford Smith et al., 2011).

The demands of decision-makers looking to facilitate and undertake longer-term, strategic transformative change in all levels of agricultural production systems are unlikely to be satisfied by the current supply of information (Smithers and Smit, 1997; Nelson et al., 2007; Sarewitz and Pielke, 2007). As a consequence, highly complex and risky investment decisions, with impact life-spans lasting up to several decades, may be based on a limited understanding of possible outcomes and consequences. Other consequences may include a possible failure of the governance system to legislate or incentivize sustainable management of the resource base (Costanza et al., 1998; Abel et al., 2006), or stifle capacity to adapt (Urwina and Jordan, 2008).

The contention that successful transformations require well planned and transparently navigated pathways (Chapin et al., 2010; Gelcich et al., 2010), has resulted in the call for a greater understanding of the processes and governance of change operating in society (Smithers and Smit, 1997), and more specifically, in agricultural production systems (Pearson et al., 2011). Indeed, even the question of why transformation processes occur in the first place remains largely unexplained (Tabara and Ilhan, 2008). Nor is it is clear how investments in R&D are best able to inform the information and policy frameworks necessary to support stakeholders at all levels. Such support may assist industry to make more informed decisions regarding fundamental changes to their operations. Though it is recognised that knowledge delivery alone is unlikely to be sufficient to inform change management, and that it must complement more constructed, emergent knowledge that is grounded in action or experience (Jonassen et al., 1999).

To this end, we draw upon the existing transition, adaptation and transformation science literature to produce a single conceptual framework aimed at understanding the information needs and policy support required by decision-makers in responding to climate change; we call this the Adaptation Action Cycles. Our approach includes drawing upon established theories and tools of stakeholder participatory engagement, and integrating them in a new way to understand the dynamics of primary production livelihoods. In particular we seek to understand the generic and enterprise-specific drivers of change, and the need for incremental and transformative adaptation actions. The Adaptation Action Cycles approach complements existing theories of transition and transformation, and associated concepts such as panarchy and regimes, by operationalising assessments at the individual and enterprise scale.

Early findings from a five-year longitudinal study of change management in the wine industry of Australia are used to offer a first validation of this new conceptualisation of incremental and transformative adaptation. The results produced from applying the Adaptation Action Cycles concept and action framework are discussed with particular reference to differences characterising the decision-making processes, and information and policy needs at incremental and transformative scales of change management. The results also provide evidence of a dependent relationship operating between incremental and transformative actions taken at different scales of enterprise within the industry (which roughly translate to different operational levels within the wine production chain).

2. Method

2.1. Review of transformation literature

Searches on peer-reviewed literature relating to transformation science were undertaken using a selection of search engines, websites and databases. Keywords used to search the databases were variations on the terms 'transformation', 'primary industry' and 'climate adaptation'. From the body of literature collated, we identified definitions of transformation and key areas of theory presently in use in agricultural and land-use research. A critical review of the definitions, the context in which they were used and associated theories was undertaken with the aim of identifying aspects that may be useful in understanding the transformation journey undertaken by primary industry stakeholders in response to climate change. From the review, a definition of transformation was developed for specific application to the study of adaptation in primary industries in Australia. The definition and selected aspects of theory were then collated within a conceptual framework, which we represent schematically as the Adaptation Action Cycles.

2.2. Validation of the adaptation action cycles

A five year longitudinal study was established in collaboration with members of the wine, peanut and livestock industries, and two rural communities in Australia. In this instance only the results from the first year of data collection in the wine industry case study are presented to illustrate the utility of the Adaptation Action Cycles framework to facilitate an understanding of the key drivers of change, the different strategies being employed by members of the industry to manage change, the relative positions of different members on their adaptation journey, and the information and policy needs of decision-makers seeking to enhance adaptive capacity.

The longitudinal study started in June 2009 and is ongoing at the time of this publication. The wine case study was established using an initial process of self-selection, with stakeholders responding to advertisements placed in key rural newspapers and on-line forums. The wine industry was selected from the thirty-five respondents for inclusion in the project on the basis of its close alignment with the project brief. Stakeholders engaging in the wine industry case study range in size from a multi-national beverage company, to medium-sized nationally-focus wine companies, each associated with grape suppliers located in pockets scattered over nearly half of the continent. The study also considers independently owned, single-farm boutique wineries. Information

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was also sourced from two wine industry bodies. The participating stakeholders ranged in terms of their present position in relation to undertaking incremental and transformational change. The adaptation journey being taken by each stakeholder is being monitored approximately annually during the course of the study. The key questions established in the Adaptation Action Cycles framework (Section 4) were used to systematically guide semi-structured interviews conducted with a sample of key stakeholders participating in the wine industry case study. A total of 15 semi-structured interviews were conducted in the first year of data collection (2010) with key decision-makers in three different sized Australian-based wine companies. These included company directors, board members, head wine makers and managers of marketing and environmental sustainability departments. The three companies are referred to as 'Wine making company A', 'B' or 'C' in the text below. Fifty growers presently engaged in supplying grapes to either one of these companies, were also engaged in similar interviews. These are referred to as 'Grape grower' below.

3. Conceptual frameworks for understanding adaptation

3.1. Review of transformation literature

The review of literature identified eighty seven articles relating to the subject of transformation in the context of agricultural or natural resource management. Forty-two of these articles specifically mentioned transformation or transition and were therefore reviewed in terms of their potential to provide a useful definition of transformation and conceptual framework to understand how R&D can best inform decision-making in primary industries in response to climate and other drivers of change.

By far the most commonly cited theory among the literature identified was the social–ecological resilience framework (Holling, 1973; Walker et al., 2004; Nelson et al., 2007). This framework espouses that social and ecological systems are intrinsically linked. Change in socio-ecological systems are described in terms of a series of distinct phases, collected described as the adaptive cycle (Holling, 2001). Adaptive cycles have been described as variable, complex, non-linear and dynamic (Marshall, 2007). They are also considered to exist at a number of scales in time, space and levels of organisation ('panarchies'), and interact across these multiple scales.

Within studies of resilience theory (e.g. Walker et al., 2004; Folke et al., 2005; Folke, 2006; Olsson et al., 2006; van der Brugge and Rotmans, 2007; Rotmans et al., 2000; Rotmans and Loorbach, 2009; Kemp and Rotmans, 2009; Loorbach and Rotmans, 2010), the term 'transition' is used to refer to a shift from one phase of the adaptive cycle to another, as detailed in the theory of transitions (Rotmans et al., 2001; Martens and Rotmans, 2005). Transitioning through the adaptive cycle may result in a complete change of state and the creation of a fundamentally new system, representing a transformation. Transformation is considered to occur when ecological, economic, or social (including political) conditions make the existing system untenable (Walker et al., 2004). Variations on this definition of transformation focus on specific aspects within resilience theory, such as the structures and processes that impact social–ecological systems, ecosystem changes, social values, agency, and economic and political change (see reviews by Olsson et al., 2006; Olsson, in press).

The theory of transitions identifies four phases which collectively describe the general pattern that transitions are considered to follow (Rotmans et al., 2000; van der Brugge and Rotmans, 2007). These include (a) pre-development, where system dynamics do not change visibly, but experimentation is occurring at the individual level; (b) take-off, where the process of structural change starts to build up momentum, due to the emergence of innovation and destabilization of the existing regime; (c) acceleration, where structural transformation occurs as a result of the accumulation and implementation of socio-cultural, economic, ecological and institutional changes, and (d) stabilization, where the system reaches a new dynamic state of equilibrium. The concept of "regime" is of central importance for transition research, since it defines the level of societal systems on which transitions are mainly analysed (Holtz et al., 2008).

Transition management is offered as a practical management framework for accelerating and guiding social innovation processes, and has co-evolved with transition theory development over the past decade (for a review of its development, see Loorbach and Rotmans, 2010). Transition management consists of a set of principles aimed at influencing, facilitating, stimulating and organising processes that contribute to a transition (van der Brugge and Rotmans, 2007).

A central concept within the transition management framework is a cycle made up of four activity clusters (Loorbach, 2007) (Fig. 2). The first activity cluster relates to the establishment of the transition arena that enables a shared understanding of the problem to be developed, along with a set of guiding principles for the envisaged transition. The second activity cluster focuses on identifying images and pathways that represent possible visions and options for the transition, and in turn allows for the development of a transition agenda. The agenda contains the goals and objectives of the transition and provides a guide for the frontrunners during the "search and learning process" of the transition. The third activity cluster builds on the transition images, pathways and agenda, by implementing transition experiments. The experiments mobilise diverse actors into contributing to the transition pathways and overall transition goals. The fourth activity cluster focuses on monitoring and evaluating the transition process itself to consider possible improvements, particularly in terms of the functioning of the transition arena, implementation of the transition agenda, insights and impacts from the transition experiments, and the rate of progress and challenges faced. The monitoring and evaluation activity is considered to stimulate a process of social learning among the different actors involved. The lessons learned during

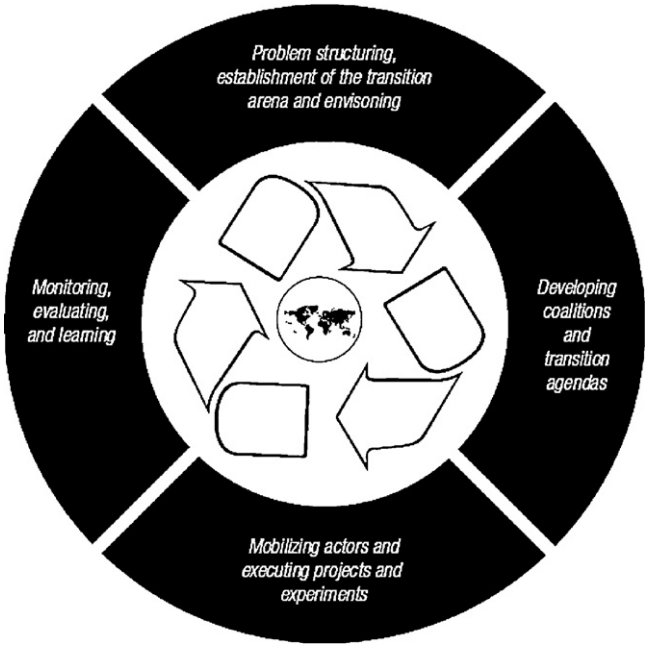

Fig. 2. The four co-evolving activity clusters within Transition Management (Loorbach, 2007).

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this set of activities are thought to inform adjustments to the vision, agenda and coalitions. Indeed, the formation of partnerships, coalitions and networks are seen as vitally important throughout all four activity clusters.

The four clusters of activities in the transition management cycle are generally thought not to occur in the above fixed sequence in practice. Rather, the concept is offered as an ideal representation of how transitions can be influenced, which can be compared and contrasted with real-world transformation processes. However, with only a limited number of applications of the theory to real-world transformations published to date (Parto et al., 2006; Loorbach, 2007; Loorbach et al., 2008; Loorbach and Rotmans, 2010), the sequence of events undertaken in practice has offered a limited range of opportunities to validate the concept. Nonetheless, we identified the transition management cycle as a useful concept for structuring an assessment of decision-making processes for adaption to climate change in primary industries.

3.2. Adaptation Action Cycles

In order to apply the Transition Management framework to the task of understanding the process of adaptation undertaken within primary industries in Australia in response to climate change, we have adapted the Transition Management Cycle (Loorbach, 2007). The principle modification is the addition of a second action-learning cycle that explicitly reflects the relative difference between incremental and transformation adaptation processes in terms of the scales of the arena, agenda, resources used, response actions developed and implemented, and their effect. We refer to the schematic representations of this conceptual framework as the Adaptation Action Cycles (Fig. 3).

The Adaptation Action Cycles depict two concentric, but linked, action-learning cycles. We offer an *a priori* hypothesis that, while the drivers of both incremental and transformative change may be similar in some cases, the information needs and policy support required by decision-makers to undertake informed and effective adaptation actions, differs according to the extent of adaptation being pursued (i.e. the maintenance of the incumbent system or process, or the creation of something fundamentally different). Further, we suggest the processes of incremental and transformative change both cycle through the same four activity clusters and are subject to the same key questions as the basis for social learning and the provision of information and policy development. However, as depicted in the schematic, the cycles operate as mutually exclusive and distinct processes.

Transition between incremental and transformational adaptation is a possible outcome that may result from knowledge or skills gained through evaluating, monitoring and learning activities. There is no pre-conceived outcome from the development and implementation of incremental or transformative adaptation actions, with capacity for infinite combinations of iterations at either scale of the concentric action-learning cycles. Indeed, there is no assumption that transformation is at all possible in all cases (Orlove, 2005). A comparative analysis of a number of transformation case studies has shown that while there may be the need for a transition from incremental adaptation to transformative adaptation, transition does not always occur, or if it does occur, does not do so in a timely manner (Olsson et al., 2006).

The action-learning foundations of the Adaptation Action Cycles framework offers the potential for social learning as both a governance mechanism, and form of praxis for shaping policies and practices in relation to climate change adaptation (Collins and Ison, 2009). As an example, the outcomes of monitoring and evaluation are thought to inform adjustments to the vision, agenda and coalitions that are subsequently formed (Loorbach, 2007). Evaluation brings with it the concept of double-loop learning (Argyris and Schön, 1978), in which the objectives are systematically revisited and questioned, and the monitoring system redesigned if necessary, and the potential for learning to better serve the purpose of systems change (van de Kerkhof and Wieczorek, 2005). Including those decision-makers responsible for managing the governance systems into the assessment, elevates social-learning to a triple level where consideration of the appropriateness of the norms and protocols of decision-making forms an integral part of adaptive management (Biggs and Rogers, 2003; Stafford Smith et al., 2009).

We hypothesize that once the outcome from a transformation strategy has been perceived as being successful, system function is

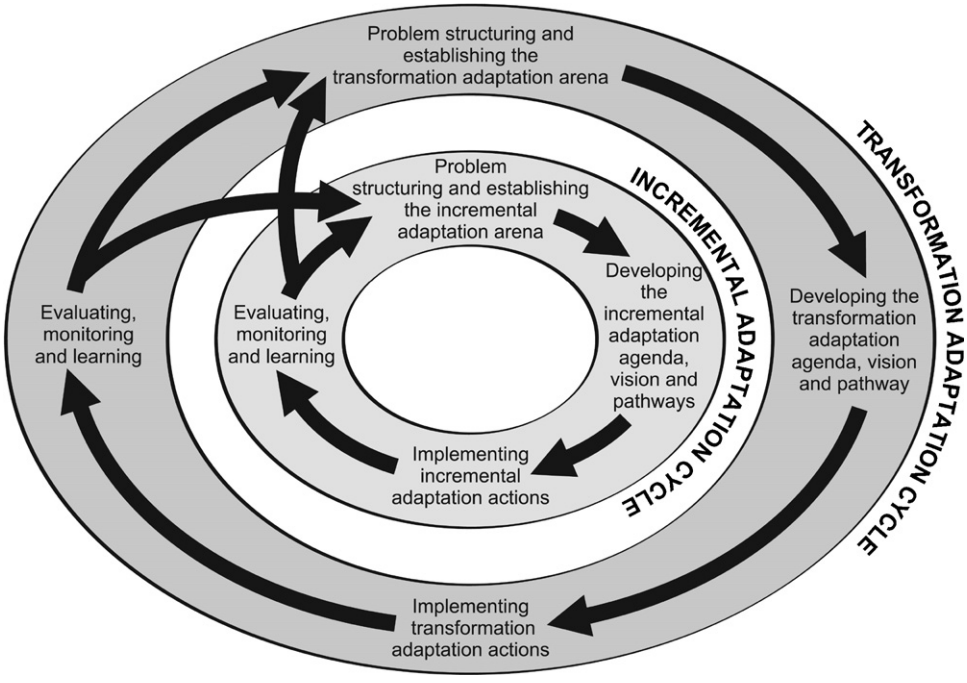

Fig. 3. Schematic representation of the Adaptation Action Cycles, depicting two concentric, but linked, action learning cycles operating at different scales.

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re-established, albeit in a potentially different form, and decision-making returns to the realms of the incremental adaptation action-learning cycle until such time when conditions warrant a further transformational change. Adopting a perspective of adaptation as a continuous cycle of incremental and transformative actions departs from the perspective of transition as an 'S'-shaped curve. The 'S' shape in this concept is seen to represent a slow rate of change at the start, which speeds up and finally tapers off at a capacity point (Prigogine and Stengers, 1984; Gunderson and Holling, 2002; Kauffman, 1995). Our adoption of the concept of a continuous adaptation cycle also addresses calls for a systematized interaction between incremental and transformation cycles, (Nelson et al., 2007; Horrocks and Harvey, 2009), and explicit recognition that the ongoing iterative management of climate change may require both short and long term, and tactical and strategic strategies (Olsson, in press).

3.3. Definition of transformation

In thinking about where incremental adaptation ends, and more fundamental transformation adaptation begins, it becomes necessary to identify the points of difference between the two response strategies. The lack of explicit definitions of incremental adaptation is conspicuous in climate change literature, but this is, in part, addressed by the numerous examples of incremental response strategies that are presented and evaluated (Howden et al., 2007). The common feature of these actions lies in their central aim of maintaining the essence and integrity of an incumbent system or process at a given scale. While double and triple loop learning may occur during both the incremental and transformative Adaptation Action Cycles, the former is characterised by the decision to continue responding to the same organisational objectives and within the same governance systems.

The term transformation has been used in a variety of contexts (Furedi, 2007; Ajakaiye and de Janvry, 2010), but defined most notably within resilience theory (Walker et al., 2004, see above). We consider transformation strategies to exist within the spectrum of adaptation capacity-building actions taken in response to a changing climate (as identified in Nelson et al., 2007). In this way, both incremental and transformational responses are considered merely to be two sub-sets within the broader suite of available adaptation strategies, which may additionally include the active decision to not take action. We therefore define transformation as: a discrete process that fundamentally (but not necessarily irreversibly) results in change in the biophysical, social, or economic components of a system from one form, function or location (state) to another, thereby enhancing the capacity for desired values to be achieved given perceived or real changes in the present or future environment. The key difference between incremental and transformational change thereby lies in the extent of change, in practice manifesting in either in the maintenance of an incumbent system or process, or in the creation of a fundamentally new system or process. Examples of incremental and adaptive changes occurring within the Australian wine industry are described below.

In this definition, transformation can be an intentional and unintentional result of decision-making and actions (Smithers and Smit, 1997). However, transformation adaptation strategies, by their very definition, involve purposeful decision-making. It is also possible to conceive both incremental and transformation adaptation processes occurring simultaneously at different sites within a complex system (Barnett, 2009). We also consider response actions taken to address climate change in a broad sense as being both opportunistic and pro-active, as well as those undertaken in a more re-active context. While the aim of transformation may be to enhance the capacity for desired values to be achieved, it is possible for both negative and beneficial outcomes to result from transformation.

Returning a system to a state that previously existed is also possible within the scope of our definition of transformation, and is a departure from definitions that consider irreversible re-organisation (Schneider, 2004), or relatively permanent change (Gallopín, 2003). Transformation strategies congruent with our definition include a change in land use or location, or increase in diversification of income streams (Howden et al., 2010), as well as a change in the scale at which the system functions.

While the definition of transformation offered above does not explicitly state the scale at which transformation has occurred, the focus on changes made in the context of desired values supports our view that transformation can occur at any level, from the individual through to the collective, industry or region. As governance and adaptive capacity operate at nested and interacting scales (Adger et al., 2005; Adger and Vincent, 2005; Abel et al., 2006), it is logical to consider that the ability to undertake incremental or transformative change at one scale, is likely to be dependent on the nature and extent of adaptive actions being taken at other interacting scales. The case study detailed below validates this by showing how transformational change is required at one level in the wine industry in order to enable incremental change to be sufficient for the industry more broadly to maintain its current function. However, the case study also shows that transformation may, under some circumstances, be largely independent of actions taken at other scales.

4. Applying the Adaptation Action Cycles framework

The need to understand the process of adaptation is increasingly being recognised as a necessary component to developing and implementing sustainable management practices, particularly in the case of agricultural production (Meinke et al., 2009; Howden et al., 2007), where there is an immediate and intimate dependency on the surrounding natural resources (Marshall, 2010; Marshall et al., 2011). In one such study, a framework, based on adaptation science, management and options, is used to understand the process of adaptation at the scale of the individual or system (Wheaton and Maciver, 1999). Understanding is gained through the posing of five key questions in the Adaptation Cycle: (i) who or what adapts; (ii) what do they adapt to; (iii) how do they adapt; (iv) what resources are used and how, and (v) what are the effects of adaptation within and across sectors (Fig. 4).

Unlike the Transition Management cycle (Loorbach, 2007), the Adaptation Cycle (Wheaton and Maciver, 1999), and in particular its five questions, explicitly probe the decision-making process and its outcomes without seeking to steer it to a predetermined conclusion. Similar to the concept of regimes (Walker et al., 2004), both desirable and undesirable outcomes can result from transformative change. However in contrast, regimes take into account a much wider context than is proposed by the agent-focused, Adaptation Cycle. The applied and action-oriented focus of the Adaptation Cycle facilitates assessment of observed decision-making processes at the individual or single enterprise scale. We have drawn on the questions embedded within the Adaptation Cycle to produce our own series of questions aimed at guiding a systematic assessment of the decision-making processes associated with incremental and transformative adaptation actions. These questions have been embedded within our Adaptation Action Cycles concept to offer an applied framework for understanding the practical information and policy support needed to promote more informed consideration of adaptation options and their implementation (Fig. 5).

As decision-making and implementation of adaptation actions reflect social norms and processes (Nelson et al., 2007), under-

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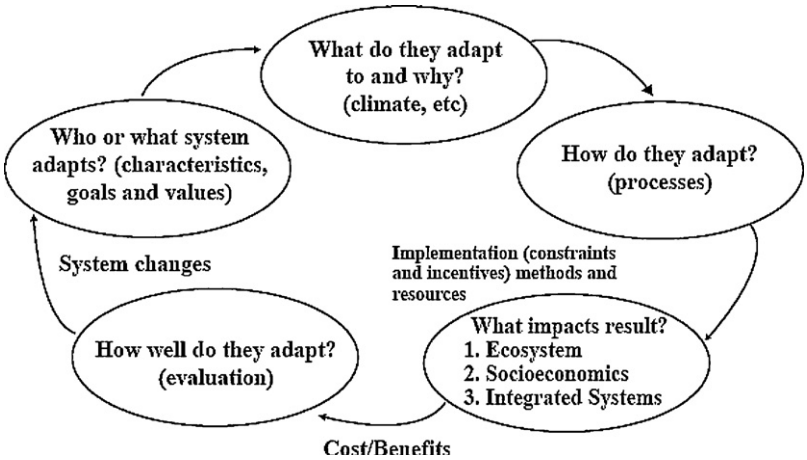

Fig. 4. The Adaptation Cycle through space and time (Wheaton and Maciver, 1999).

standing gained from the use of the Adaptation Action Cycles applied framework will be based on the decision-maker's perception of various factors and conditions leading up to, and following on from, a decision, together with their views on the subsequent actions and outcomes. The importance of using stakeholder perceptions, particularly of their abilities, opportunities and resources to support change, in preference to discrete measures, has been shown to be useful in understanding adaptation (Grothmann and Patt, 2005; Gardner and Ashworth, 2008).

5. Case study: the wine industry in Australia

Here we describe a case study undertaken in collaboration with the wine industry in Australia as an initial test of the inductively developed Adaptation Action Cycles concept and applied framework. The wine industry in Australia consists of a broad range of grape and wine-producing enterprises. At one end of the scale are the wine branches of large international beverage companies that manage their own wineries, as well as contracting grapes from suppliers scattered over nearly half of the continent. The industry also comprises a number of medium-sized companies characterised by their regional focus on wine production. These also use grapes produced on their own vineyards, as well as those purchased from independent growers. At the smaller end of the enterprise scale are a plethora of independently owned, single-farm boutique wineries. The case study captured responses from all three scales of enterprise. The size of an enterprise generally corresponded to ownership type, i.e. large vineyards were often corporately owned, while small vineyards tended towards private ownership. The character of the decision-making processes operating across these enterprises was correspondingly diverse, but similarities in the key drivers influencing the decisions faced were largely common across the industry. These include the

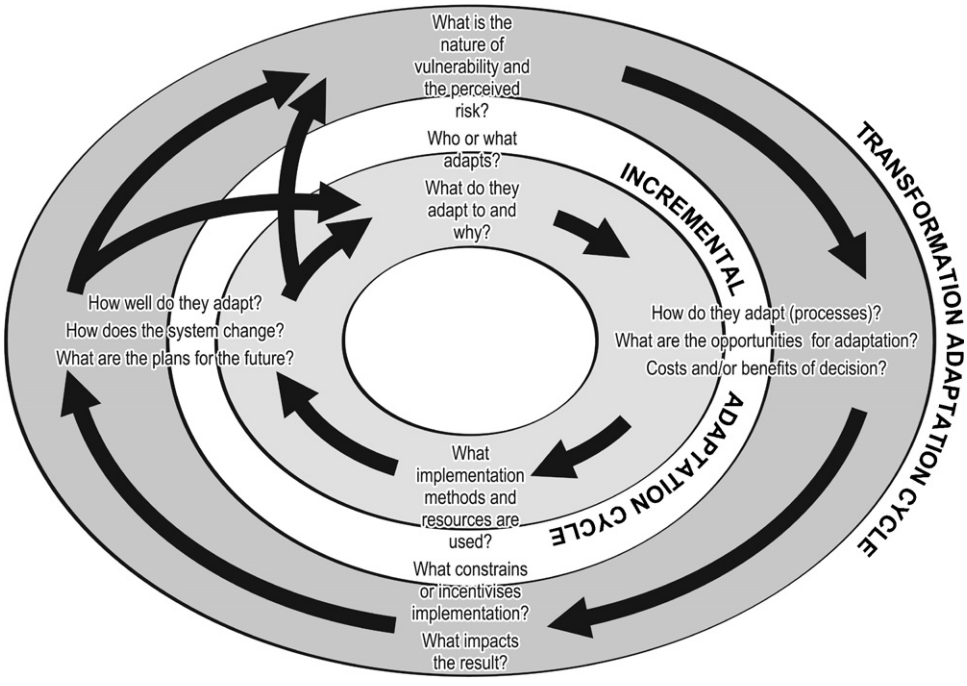

Fig. 5. The Adaptation Action Cycles framework, showing key questions for guiding a systematic assessment of the decision-making processes used in managing incremental and transformative change at different scales. Based on the activity clusters depicted in the Adaptation Action Cycles concept (Fig. 3), and the five questions incorporated in the Adaptation Cycle (Wheaton and Maciver, 1999) (Fig. 4).

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present global over-supply of grapes, effect negative impact of the global financial crisis, the need to manage a highly variable intra- and inter-annual climate, the trend for a reducing availability of water, rapid increases in energy costs, and changes in consumer taste. Climate change was considered to be a direct driver of change in the wine industry in terms of increasing temperatures and heat stress; however, it was also thought to be interrelated to many other drivers, such as declining supplies of irrigation water, rising energy costs, and changes in marketing foci and consumer preferences for lighter wine styles and more environmentally conscious production practices. Climate change will likely exacerbate many of these drivers (Webb et al., 2008), and potentially contribute to their continuation into the future. This array of drivers and their influence on the vulnerability status of the Australian wine industry reflects similar settings in other wine producing nations (Holland and Smit, 2010).

5.1. Differences in the adaptation decision-making processes

Data collected to date suggests that marked differences exist between those grape and wine producing stakeholders and enterprises that are managing change at the incremental scale, and those who have transformed, or are considering there may be a need to do so at some time in the future (Table 1). The differences are evident at all of the four stages of the action-learning cycle, and for each scale of adaptation (i.e. incremental and transformative) there appears to be an element of internal coherency between the four comprising stages.

Differentiating features can be seen in how the two distinct sets of stakeholders mentally structure the problem of managing change and the agenda in which they will operate. Incremental adaptors are adopting a short-term, reactive focus on maintaining the present system. This contrasts with transformative adaptors who are more proactively managing drivers of change to deliver outcomes in both the present and the future. This latter group of stakeholders are readily acknowledging the need to deal with uncertainty in the future and are willing to question the fundamental functioning of their enterprise.

Incremental adaptors can also be characterised by the limited amount of data that they use to inform adaptation decision-making, and the lack of distinction with which they consider climate in respect to other drivers of change. In contrast transformative adaptors appear to use a greater source of information in their decision-making process compared with incremental adaptors. Transforming adaptors also perceive climate change as posing a distinct management challenge from other issues. A greater emphasis on considering the costs and benefits of management strategies is also evident at the transformative scale.

The range of factors incentivizing the implementation of actions differs between the two scales of adaptors. Incremental scales of change again reflect a reactive response to external drivers, and contrasts with the more pro-active approach to shaping the future that is seen in the transforming stakeholders. Both scales of adaptation have barriers to effecting change, and these too appear to be distinct. Most prominent of these is belief in anthropogenic climate change. Many stakeholders not believing in human-induced changes in climate also considered that incremental change alone will be sufficient to manage future climate. Whereas those operating within an adaptation arena that also includes the potential need to transform, tend to perceive anthropogenic climate change as a real phenomenon. Within this group were also a number of stakeholders who were willing to accept the need for transformation regardless of their belief (or not) in anthropogenic climate change, because they considered the action would offer benefits regardless.

We also observed differences in how both sets of adaptors undertook evaluation, monitoring and learning. Incremental adaptors critiqued their performance and needs for the future within the bounds of past experience, and using a short-term future horizon. Transforming adaptors perceived the role of evaluation, monitoring and learning to be more ongoing, and in line with their more expansive structuring of the problem and adaptation arena, tended to seek feedback from other actors in the value chain.

5.2. Adaptation strategies and incremental actions

Incremental adaptation of grape production practices to changes in climate is widespread across all sizes of enterprises in the industry. Common strategies include early harvesting of the crop in response to accelerated phenology (Petrie and Sadras, 2008), manipulation of the crop canopy (Schultz and Stoll, 2010), selection of drought-tolerant root stock (Cox, undated), and the use of water efficient technologies and practices (CRCV, 2005). A number of other factors are driving incremental change in the wine industry, including the need for greater economic efficiency and improvements in the quality standards of grapes supplied to large wine producers. While the drive for economic efficiency is largely independent of scale, the need for improvements in the quality of grapes produced is being driven largely from higher levels outside the industry through national and global consumer demands and legislative pressures. The Australian Wine Research Institute, CSIRO, and the state departments of agriculture are key providers of wine and grape related R&D to the industry. Together with informal on-farm experimentation by growers, the body of information provided by these sources is considered sufficient to satisfy the key needs of many stakeholders making short-term tactical decisions regarding the incremental adaptation of present grape growing and processing practices. While the quantity of information provided may appear to be sufficient, there are questions regarding the quality of some of it.

5.3. Transformation and scale dependency

At present, transformational change in the industry is occurring either from agency to actively change, or from coping with externally imposed changes, through two main mechanisms. In one instance enterprises focused on supplying grapes to wine producers (i.e. grape growers), are relocating to cooler grape growing regions. A primary incentive for this action stems from grape producers operating in, or being prepared to relocate to, more climatically favourable regions, being favoured by wine producers in terms of new and ongoing contractual supply agreements. Grape supplies in increasingly undesirable agro-climatic regions are experiencing the early termination of supply contracts, or are failing to have their contracts renewed by wine producers. Transformation is also occurring where wine making companies are purchasing additional vineyards in cooler regions of the continent, e.g. Tasmania. Where growers and wine making companies have transformed in this way, their anticipation is that by incorporating climate-sensitive practices and technologies into their newly establishing vineyards, changes in climate can be managed in the foreseeable future largely through incremental adaptation actions. In these cases, grape production enterprises over the past decade or so have cycled through a series of incremental adaptation actions, a fundamental transformational shift, and returned their ongoing change management to incremental actions. This series of events is captured by the Adaptation Actions Cycles framework.

The transformation of a critical mass of grape producing enterprises is enabling one large wine producer to maintain

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Table 1
Examples of features that differentiate the incremental and transformative decision-making processes undertaken by wine industry stakeholders.

Stage of the adaptation action cycle (and questions used operationalise it)	Incremental adaptation	Transformative adaptation
Problem structuring and establishing the adaptation arena What is the nature of vulnerability and the perceived risk? Who or what adapts? What do they adapt to and why?	Focus on change management for the short-term. "*We're worried about what we do next week rather than what we're doing in seven or 10 years time.*" [C] Reactive management of change, focusing on current conditions. "*I think we're more reactive [than] proactive. I don't think that there's any kind of looking at the tea leaves and saying this is going to happen to the climate so therefore we should do this.*" [C] Change management is focused on finding ways to keep the present system in operation. "*My view is that if you haven't got enough water, then you move the water to the location; you don't move the location to the water.*" [A]	Proactive management of present and future change, with a view to influencing it. "*We actually try and create the market for it and then plant the vines.*" [A] Uncertainty in the future is acknowledged and built into decision-making. "*We don't factor on - now two degrees, the number might be wrong but it's still the thinking. We're going to accept that there's going to be at least two degree temperature rise.*"[B] Managing change includes questioning the effectiveness of existing systems and processes. "*We just can't keep our decision making process the same.*" [B]
Developing the adaptation agenda, vision and pathway How do they adapt (processes)? What are the opportunities for adaptation? Costs and/or benefits of decisions?	Limited source of information used to determine the need for, and the selection of, adaptation actions (due to either not sourcing, understanding, or trusting available information). "*They say jump, we say how high.*" [GG] Winery adaptation strategies focus on managing short-term risk and maintaining quality and quantity. "*If any one of those regions has a bad year we then just top it up with other regions. That's why, I guess, we're able to maintain a fairly consistent quality.*" [C] Climate is only one of many factors of change, and can be managed by addressing sustainability more generally. "*We've actually been trying to get the growers to think more globally about their situation by introducing them into an environmental management system so they actually think carefully about their sustainability decisions around reliability of their water resource and those sorts of things.*" [C] Current supply of information is considered sufficient to inform change, but it is not reality, and it is difficult to decide what is valid/good information and how to apply it. "*There is information out there about climate change but it has questionable validity. There is a mix of good information with bad and you have to work out what to trust.*" [GG] Perceived as having limited opportunities to implement change. "*We've been on very low capital budgets over the last several years. So that really means that our ability to implement change is fairly restricted.*" [A]	Information and input into decision-making is collated from a wide range of sources and is acted upon even if it is recognised that the information, input and sources contain uncertainties. *Each person within our group may play an integral role in a certain project with regards to climate change.* [A] Broad range of information used to determine the need for, and the selection of adaptation actions. *We just kept looking at it [Tasmania] and it just kept ticking the boxes.*" *Wine making company* [B] Strategies for adapting to change become differentiated for different sectors/levels of the industry. "*We'd put more of that risk then back on the growers, so it's up to the growers then to become adaptive or more flexible.*" [C] Climate change is only one of many factors of change, but it poses a distinct challenge. "*You know, and they know that there are good years and bad years. I mean, they've been experiencing change for over 100 years. While climate change is - it's a different - it's another challenge.*" [B] Directly managing for climate change will result in additional benefits. "*I think [changing trends in climate] are stimuluses to get ourselves into some of these things, and then they do yield other benefits; but they're often bridges you would not have crossed unless you were pushed to do it.*' [A] Benefits resulting from managing climate change considered to outweigh costs over the long-term. "*But I just think that the fact we talk about these things and we're actively involved in them, what's the worst that could happen? Nothing, you know. [If] there's no climate change, it turns out to be fluctuations in the natural, we started 30 years ago and who cares if that's what happens. But at least we will have got so many other benefits of some of these thinkings anyway.*" [A]
Implementing adaptation actions What implementation methods and resources are used? What constrains or incentivizes implementation? What impacts the results?	Factors incentivizing change include: delivering to contractual obligations (in relation to quality, quantity, and methods of production); tracking current market demand. "*What the winery needs is consumer driven and we go along with whatever the government and the winery want.*" [GG] Constraints to effecting change include: belief that the current variability in climate is natural (i.e. the lack of belief in anthropogenic climate change inhibits long-term change); long-term contractual obligations; close to retirement age and lack of succession planning; limited or inflexible access to financial capital; limited availability of supplementary irrigation water. "*Climate change is a naturally occurring event. We can't do a lot about it.*" [GG]	Factors incentivizing change include: attracting a new supply contract; potential to produce premium wines; perceived opportunities arising in new locations through increasingly suitable climatic conditions; perceptions of new locations satisfying consumer aesthetic and ethical demands; acceptance of anthropogenic climate change; motivation to act now for future benefit; flexibility to access financial capital. "*We would say, look here's a contract and you go and move, you plan the vineyard, we'll keep buying the fruit off of you under that contract. We'll give you 10 years, 15 years, which are long contracts now but that's what we might have to do again to get these people to move.*" [C] Constraints to effecting change include: high attachment to place (including historic legacy); high attachment to occupation. "*I'm not sure what I'd be doing if not growing grapes, for me it has to be grapes, that's my passion.*" [GG]

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Table 1 (*Continued*)

Stage of the adaptation action cycle (and questions used operationalise it)	Incremental adaptation	Transformative adaptation
Evaluating, monitoring and learning How well do they adapt? How does the system change? What are the plans for the future?	Evaluation of performance limited by belief that the future won't deliver anything beyond the current system. "*There have been 5 years of extreme climatic changes and there won't be anything like that in the future, it is downhill from here.*" [GG]. Plans for the future are focused on surviving in the short-term. "*Probably the penny hasn't quite dropped there yet, I don't think. Because, again, I think they're more about, in the current environment, how the hell am I going to survive economically.*" [C]	Continuous evaluation and monitoring of the system in response to all scales of change management. "*Well, I mean, I think it's just got to be this flexibility. It's not just about buying a vineyard in Tasmania. Like, okay, problem solved, we're right. It's the whole, just with all your vineyards, I think. Just really keeping tabs on how might those change? What varieties might you use? What wine styles might you make? I mean, you've just got to think.*" [B] Active feedback between different sectors of the value chain increase opportunities for reflective double loop learning. "*It's not just a dictatorship from the top up, you know, a lot of information comes from the bottom.*" [A] An integral part of planning and managing future risk includes building the capacity to create a fundamentally new system or process, that is flexible and able to be acted upon if required. "*It's nice to have a few things simmering away ready to turn the heat up when you need it.*" [A]

functioning at their operational level, through incremental adaptation actions alone. In this instance, incremental adaptation at the level of the wine production company (via changes in whom and where it engages in grape supply contracts) is dependent upon the transformative actions of grape suppliers at a smaller scale, and generally the primary production end of the wine production chain.

A number of strategies for change management are in operation within medium-sized wine companies. In one wine producing company, a combination of promoting incremental adaptation in its grape suppliers' operations, and a regional focus on company marketing strategies, are considered sufficient to maintain a viable wine industry into the foreseeable future. This strategy is resulting in little change in the contractual ties that exist between the wine company and the growers that form its long-standing supply base. In contrast to the above larger wine producing company, a viable wine production chain is being pursued through the implementation of incremental adaptation actions at both the grape production level, and the wine production and sales levels. What is similar to the above however, is the need for the two scales of enterprises (and operational levels) involved in these relationships to have adaptation strategies that are complementary and temporally coordinated. The strategy of combining transformative and incremental change management actions in the first example, and incremental change actions alone in the second example, both demonstrate the need for effective adaptation to be considered and coordinated across a number of scales.

A second medium-sized wine company is adopting an alternative approach to change management. By purchasing an additional winery in a cool-climate grape producing region of Tasmania, this company has undertaken its own transformational change for a specific wine product range (i.e. sparkling white wines). However, the company is continuing a strategy of incremental adaptation in its long-standing grape and wine production locations. The new and existing small scale enterprises supplying grapes to this wine producing company can now continue to rely on incremental adaptation actions alone for the foreseeable future, in part due to the transformative change that has occurred at the operational level above them. While the direction of the dependency across scales in this instance is reversed from the example above, the combination of transformative and incremental change is again scale dependent.

At the smaller end of wine production, a number of boutique wineries are undertaking fundamental transformational change. Here owners are choosing to either undertake wholesale *in situ* land use change (i.e. substituting grape production for alternative activities such as tourism or the growth of other crop species), diversify into additional on and off-farm income-generating activities, relocate their wine production enterprises to more agro-climatically suitable regions, or alternatively 'mothball' their assets temporarily from grape and wine production. The intention of the latter strategy is to either resume grape and wine production, or sell the enterprise, at a later date when social, economic or climatic conditions are perceived to be more favourable. This suite of transformation strategies is being undertaken regardless of the scale of adaptive actions occurring at other operational levels in the wine industry. The independent nature of transformation in these cases is facilitated by the domain of influence covered by key decision-makers. That is to say, the owners of boutique wineries are able to make decisions that cover the full extent of the value chain, from the growing of grapes in the field through to the sale of wine at the cellar door.

5.4. Information and policy needs

The broad range of scales of enterprises operating within the Australian wine industry, their interactions along the wine value chain, and differences in stimuli and strategies adopted for adapting to change, are reflected in a similarly diverse range of information needs and policy support requirements. Clearly, the information and policy needs required to support and enable informed decision-making by for example, boutique wine makers undertaking transformational change, differs from that required by members of the industry undertaking incremental adaptation. While incremental adaptation options for grape production are being addressed by a handful of studies (e.g. Webb et al., 2010), the information provided is noticeably limited in its consideration of all aspects of change management in the wine production chain (Fearne, 2010). Even more limited is the supply of information of a biophysical, social or economic nature that is needed to support the potentially more complex and risky decision-making associated with transformative change (Verweij and Thompson, 2006).

The absence of any consideration of human agency, and in particular cognitive barriers that may inhibit stakeholders undertaking rational transformative actions, are noted in the context of sustainable wine production systems (Holland and Smit, 2010). This contrasts with evidence collected in this study to indicate that many wine industry stakeholders in Australia have strong emotional connections to their farms, lifestyles, regions and participation in wine production. If undesirable outcomes are to be avoided, it will therefore be necessary to consider high levels of attachment to place (Devine-Wright and Clayton, 2010) and

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occupation (Becker and Carper, 1956) as well as attitudes to risk (e.g. Verweij and Thompson, 2006), in the future foci of R&D aimed at supporting effective decision-making related to transformation-related strategic planning, policy making and program development.

Tailoring R&D and governance structures to better support key decision-makers will also require consideration of the specific impacts of adaptation technologies and policies not only on the individual focal scales, but also for interacting scales within the industry (Folke et al., 2010), and across the multiple components of the wine production chain. The Adaptation Action cycle framework is a useful tool for facilitating this consideration of change at different types and scales of business operation. Importantly, our analysis has highlighted dependencies operating across scales and different stages in the wine production chain that may not be readily observed from focusing on only one scale of stakeholders. The broad range of business models, adaptation strategies employed and agro-climatic regions involved in grape and wine production in Australia offers a high level of adaptive capacity for the industry as a whole.

6. Discussion and conclusions

The lack of an understanding of the social, economic and environmental conditions prevailing at the time of transformative change, the complexity of the associated decision-making processes, and the relevance of temporal and spatial scale in enabling adaptation, highlights a knowledge gap in the information needs and policy support required by stakeholders in the primary industries (Smithers and Smit, 1997; Sarewitz and Pielke, 2007; Nelson et al., 2007). This shortfall has prompted the development of the Adaptation Action Cycles concept and applied framework for supporting decision-making and change management strategies at the individual or enterprise level, when moving between incremental and transformative actions. Our results suggest that the Adaptation Action Cycles concept effectively synthesizes existing knowledge from the fields of change management and action-learning theory, reflects at least the decisions made within one primary industry, and can potentially support the practical needs of other sectors of society to adapt to change.

The Transition Management cycle (Loorbach, 2007) offers a basis for understanding the activities taken by actors involved in transitioning between states with the aim of adapting, and underpins the Adaptation Action Cycles concept. In published case studies to date, Transition Management has been used as a deliberative process aimed at influencing and accelerating the transition process (Parto et al., 2006; Loorbach, 2007; Loorbach et al., 2008; Loorbach and Rotmans, 2010). As such, Transition Management has played an active role in determining the outcomes of the transformation process. Combining the Transition Management cycle with a version of the key questions posed in the Adaptation Cycle (Wheaton and Maciver, 1999) emphasised a shift away from an externally-conceived, predetermined outcome, towards a more explicit probing of stakeholders' present decision-making processes and strategies for managing change. Importantly, adopting an agent-focused perspective facilitates a contextual understanding of some of the practical information and policy support needs of those seeking to adapt (Park et al., in press). This information is considered to complement more constructed, emergent knowledge that is grounded in action or experience (Jonassen et al., 1999).The Adaptation Action cycles approach also complements the much wider contextual focus associated with the concept of regimes (Walker et al., 2004). By supporting change at the individual and enterprise scale, it fulfils a need that regimes cannot. The resulting Adaptation Action Cycles offers a heuristic to understand the drivers of change and the dynamics of decision-making in complex adaptive systems with an emphasis on supporting, rather than guiding them. In terms of socio-ecological systems (Holling, 2001) the dimensions that Adaptation Actions Cycles concept and applied framework considered included the scale of the industry.

In combining existing frameworks of change management, we have drawn from both the resilience and vulnerability paradigms. Although sometimes considered to hail from differing disciplinary foci, and offering competing discourses, theories and tools of analyses, the resilience and vulnerability approaches appear to offer some convergence in respect to the study of adaptation (Adger, 2006; Gallopín, 2006; Nelson et al., 2007; Turner, 2010). This has resulted in a blurring of concepts and methodologies (e.g. Osbahr et al., 2008), and the potential to enhance understanding of change processes operating at different timescales. We show that the Adaptation Actions Cycles can aptly represent a relatively short timeframe – typically less than ten years. Such timeframes instantly make the concept amendable to managing change as they readily correspond to the timeframes that decision-makers use. This short snapshot of change management is in stark contrast, but highly complementary to, the Panarchy adaptation cycles (figure '8'). These generally represent timeframes that are considerably longer than ten years, and are even inclusive of evolutionary timescales. As frequently described within the Panarchy literature, adaptation is nested across scales, and while evolutionary timescales will influence how societies evolve, the decisions that societal leaders make using relatively short timeframes (of say five to ten years), will inevitably influence the ultimate adaptation outcomes in the longer term. The Adaptation Action Cycles concept and framework offers an assessment approach to understand change processes occurring within the decision-making timeframes typically used in the daily management of enterprises and human systems.

The Adaptation Action Cycles depicts two concentric, but linked, action learning cycles. Assessment of change management in the Australian wine industry case study supports the idea that adaptation actions cycle through a continuous series of incremental and/or transformative shifts. Learning by decision-makers has played a key role in determining the necessity for a transition between incremental and transformative adaptation within the wine industry, and underpins the iterative management of change over time that is evident at all scales and operational levels within the industry.

The varying combinations of incremental and transformative adaptation actions being employed throughout the wine industry suggests that there are few, if any, constraints on the temporal sequence of incremental and transformative adaptation actions undertaken by any single enterprise, subject to the presence of thresholds. However, there is a need for enterprises that interact along the wine value chain to identify and understand the nature of their interdependency and coordinate their adaptation activities. Methods such as the Adaptation Action Cycles may assist in assessing such interactions and the thresholds that prompt action at different scales. Looking at multiple scales will be necessary if nested strategies for change management are to be effectively developed and implemented, Transformative decision-making, by its very nature, involves greater uncertainty than that associated with incremental adaptation. Risk management and robust decision-making will thus represent core features of transformation (Stafford Smith et al., 2011). Perhaps somewhat less obvious than physical transformation actions is the need for individuals to undertake a psychological transformation in personal identity or behavioural change (Grothmann and Patt, 2005; Marshall et al., 2007; Lankester et al., in press). The wine case study suggests that transformation is more easily undertaken, and achieved relatively

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sooner, in smaller scale enterprises. We found no transformation present in the global company studied, only partial transformation in one of the medium-sized grape and wine producing companies, and numerous cases of transformation among small scale independent grape growers and wine producers.

The wine case study also highlighted the dependency between spatial scales in terms of the need for, and the capacity to undertake, either incremental or transformative change. Transformation occurred at one operational level in the wine industry for incremental adaptation options alone to be sufficient to manage similar drivers of change at another operational level. This direction of dependency has previously been noted (Folke et al., 2010). However, the dependent relationships evident in the wine industry are operating in both directions, that is to say, transformation can equally occur at either the larger or the smaller scale for this cross-scale dependency to exist. The case study also highlights the potential for the desired values that are driving transformation, to not necessarily reside at the scale that is required to transform. Using a nested approach to integrate knowledge of dependency relationships existing across scales is essential if we are to avoid the creation of, and providing ongoing support for, organisational and institutional structures that promote compartmentalized decision-making processes that ultimately undermine adaptive capacity and longer-term sustainability (Ludwig et al., 1993; Adger et al., 2005; Crowder et al., 2006).

In addition, it is interesting to note that there is also the potential for transformation to occur independent of scale where an individual enterprise comprises the full extent of the value chain. Incremental adaptation is similarly independent of scale under such circumstances. Notwithstanding this latter finding, the broader operation of governance and adaptive capacity at nested and interacting scales (Adger and Vincent, 2005; Abel et al., 2006), in this instance seen in the wine industry of Australia, will mean that systematic application of the Adaptation Actions Cycles framework must be focused on multiple scales and multiple case studies. This will enable both location and case-study specific, as well as generic pre-conditions and thresholds for transformative change, to be identified and used to more effectively align the supply of information and policy support to those decision-makers seeking to enhance capacity to adapt. The wine industry case study only provided validation of the Adaptation Actions Cycles framework to relocation as a transformative strategy, and it has yet to be validated for instances where alternative transformation actions are undertaken, e.g. change in scale of operation, substantial diversification.

The *a priori* hypothesis that the information needs and policy support required by those undertaking incremental adaptation are not necessarily the same as those looking to achieve transformative change, is a significant point of departure introduced in the Adaptation Action Cycles compared with previous concepts of adaptation and change management. Application of the Adaptation Action Cycles to the Australian wine industry case study has validated this proposition. While the drivers of both incremental and transformative change may be similar across the wine industry, the information needs and policy support required by decision-makers to undertake informed and effective adaptation actions differs according to the extent of scale being pursued (i.e. the maintenance of the incumbent system or process, as compared to the creation of a fundamentally different enterprise).

Clear differences exist among the grape and wine producing enterprises in their strategies to manage change. Our initial analyses suggest that the diversity of business models, adaptation strategies being employed, and agro-climatic regions in grape and wine production in Australia, offers a high level of adaptive capacity for the industry as a whole. It is our contention that the Adaptation Action Cycles offers an effective concept and applied framework for assessing this diversity in terms of the R&D and policy support needed to enable adaptive capacity to operate. The Adaptation Action Cycles may also have wider applicability in helping to support decision-making and adaptive management in other sectors of society looking to respond to change. Further evaluation of the Adaptation Action Cycles as a tool for supporting and understanding change is needed to assess its efficacy in the context of other industries, countries and social systems, as well as a range of demographics.

Acknowledgements

We thank Mark Stafford Smith, Iain Walker, Anna Carr, Brian Walker, Cecil Camilleri and Russell Johnstone for their very helpful comments on this paper as it developed.

References

Abel, N., Cumming, D.H.M., Anderies, J.M., 2006. Collapse and reorganization in social–ecological systems: questions, some ideas, and policy implications. Ecology and Society 11, 17., http://www.ecologyandsociety.org/vol11/iss1/art17/.
Adger, W.N., 2006. Vulnerability. Global Environmental Change 16, 268–281.
Adger, W.N., Arnell, N.W., Tompkins, E.L., 2005. Adapting to climate change: perspectives across scales. Global Environmental Change 15, 75–76.
Adger, W.N., Vincent, K., 2005. Uncertainty in adaptive capacity. Geoscience 337, 399–410.
Ajakaiye, O., de Janvry, A., 2010. Agricultural sector performance and a green revolution in Africa: an overview. Journal of African Economicies 19, ii3–ii6.
Argyris, C., Schön, D.A., 1978. Organizational Learning: A Theory of Action Perspective. Addison-Wesley, Reading, MA.
Barnett, A., 2009. No easy way out. Nature Reports Climate Change 3 , doi:10.1038/climate.2009.106 (accessed 12.11.10).
Becker, H.S., Carper, J.W., 1956. Elements of identification with an occupation. American Sociological Review 21 (34), 1–348.
Biggs, H.C., Rogers, K.H., 2003. An adaptive system to link science, monitoring, and management in practice. In: du Toit, J.T., Rogers, K.H., Gibbs, H.C. (Eds.), The Kruger Experience: Ecology and Management of Savanna Heterogeneity. Island Press, Washington, pp. 59–80.
Chapin, F.S., Carpenter, S.R., Kofinas, G.P., Folke, C., Abel, N., Clark, W.C., Olsson, P., Stafford Smith, D.M., Walker, B., Young, O.R., Berkes, F., Biggs, R., Grove, J.M., Naylor, R.L., Pinkerton, E., Steffen, W., Swanson, F.J., 2010. Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Trends in Ecology and Evolution 25, 241–249.
Collins, K., Ison, R., 2009. Living with environmental change: adaptation as social learning. Environmental Policy and Governance 19, 351–357 Special issue: living with environmental change: adaptation as social learning.
Costanza, R., Andrade, F., Antunes, P., van den Belt, M., Boersma, D., Boesch, D.F., Catarino, F., Hanna, S., Limburg, K., Low, B., Molitor, M., Pereira, J.G., Rayner, S., Santos, R., Wilson, J., Young, M., 1998. Principles for sustainable governance of the oceans. Science 281, 198–199.
Cox, C., undated. Rootstocks as a management strategy for adverse vineyard conditions. Water & Vine Managing the Challenge, Factsheet 14. GWRDC, Australia. http://www.gwrdc.com.au/webdata/resources/factSheet/Module14RootstocksAsManagementStrategy.pdf (accessed 19.01.10).
CRCV, 2005. How to start irrigating with less water. Viti-notes. Cooperative Research Centre for Viticulture. http://www.gwrdc.com.au/webdata/resources/factSheet/27IrrigatingWithLessWater.pdf.
Crowder, L.B., Osherenko, G., Young, O.R., Airamé, S., Norse, E.A., Baron, N., Day, J.C., Douvere, F., Ehler, C.N., Halpern, B.S., Langdon, S.J., McLeod, K.L., Ogden, J.C., Peach, R.E., Rosenberg, A.A., Wilson, J.A., 2006. Resolving mismatches in U.S. ocean governance. Science 313, 617–618.
Devine-Wright, P., Clayton, S., 2010. Introduction to the special issue: place, identity and environmental behaviour. Journal of Environmental Psychology 30, 267–270.
Fearne, A., 2010. Sustainable Food and Wine Value Chains. Department of the Premier and Cabinet, Adelaide, Australia. , In: http://www.thinkers.sa.gov.au/lib/pdf/Fearne_Final_ReportCopyforWeb.pdf.
Folke, C., 2006. Resilience: the emergence of a perspective for social–ecological systems analyses. Global Environmental Change 16, 253–267.
Folke, C., Hahn, T., Olsson, P., Norberg, J., 2005. Adaptive governance of social–ecological systems. Annual Review of Environmental Resources 30, 441–473.
Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T., Rockstrom, J., 2010. Resilience thinking: integrating resilience, adaptability and transformability. Ecology and Society 15, 20., In: http://www.ecologyandsociety.org/vol15/iss4/art20/.
Furedi, F., 2007. Coping with adversity: the turn to the rhetoric of vulnerability. Security Journal 20, 171–184.

Gallopín, G.C., 2003. Box 1. A systemic synthesis of the relations between vulnerability, hazard, exposure and impact, aimed at policy identification. In: Economic Commission for Latin American and the Caribbean (ECLAC). Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters, ECLAC, LC/MEX/G.S., Mexico, DF, pp. 2–5.

Gallopín, G.C., 2006. Linkages between vulnerability, resilience, and adaptive capacity. Global Environmental Change 16, 293–303.

Gardner, J., Ashworth, P., 2008. Towards the intelligent grid: a review of the literature. In: Droege, P. (Ed.), Urban Energy Transition: From Fossil Fuels to Renewable Power. Elsevier, Oxford, UK, pp. 283–308.

Gelcich, S., Hughes, T.P., Olsson, P., Folke, C., Defeo, O., Fernández, M., Foale, S., Gunderson, L.H., Rodríguez-Sickert, C., Scheffer, M., Steneck, R.S., Castilla, J.C., 2010. Navigating transformations in governance of Chilean marine coastal resources. Proceedings of the National Academy of Sciences of the United States of America 16794–16799 107.

Grothmann, T., Patt, A., 2005. Adaptive capacity and human cognition: the process of individual adaptation to climate change. Global Environmental Change 15, 199–213.

Gunderson, L.H., Holling, C.S. (Eds.), 2002. Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington, DC.

Hare, B., Meinshausen, M., 2006. How much warming are we committed to and how much can be avoided? Climatic Change 75, 111–149.

Holland, T., Smit, B., 2010. Climate change and the wine industry: current research themes and new directions. Journal of Wine Research 21, 125–136.

Holling, C.S., 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4, 1–21.

Holling, C.S., 2001. Understanding the complexity of economic, ecological, and social systems. Ecosystems 4, 390–405.

Holtz, G., Brugnach, M., Pahl-Wostl, C., 2008. Specifying regime – a framework for defining and describing regimes in transition research. Technological Forecasting and Social Change 75, 623–643.

Horrocks, L., Harvey, A., 2009. The Implications of 4+ °C Warming for Adaptation Strategies in the UK: Time to Change? Four Degrees and Beyond. Environmental Change Institute, Oxford, UK. , In: http://www.eci.ox.ac.uk.external.vkontakte.antiblock.ru/4degrees/.

Howden, S.M., Soussana, J.-F., Tubiello, F.N., Chhetri, N., Dunlop, M., Meinke, H., 2007. Adapting agriculture to climate change. PNAS 104, 19691–19696.

Howden, S.M., Crimp, S.J., Nelson, R.N., 2010. Australian agriculture in a climate of change. In: Jubb, I., Holper, P., Cai, W. (Eds.), Managing Climate Change: Papers from the GREENHOUSE 2009 Conference. CSIRO Publishing, Melbourne, pp. 101–111.

Jonassen, D.H., Peck, K.L., Wilson, B.G., 1999. Learning with technology: a constructivist perspective. Special Education Technology, 16. Prentice Hall, ISBN 013271891X.

Kauffman, S.A., 1995. At Home in the Universe: the Search for Laws of Self-organization and Complexity. Oxford University Press, USA.

Kemp, R., Rotmans, J., 2009. Transitioning policy: co-production of a new strategic framework for energy innovation policy in the Netherlands. Policy Sciences 42, 303–322.

Lankester, A., Marshall, N.A., Cottrell, A., Gordon, I., Sutton, S. Individual learning in communities of practice in the north Australian beef grazing rangelands: transformative or not? Agriculture and Human Values, in press.

Loorbach, D., 2007. Transition Management: New Mode of Governance for Sustainable Development. International Books, Utrecht, The Netherlands.

Loorbach, D., Van der Brugge, R., Taanman, M., 2008. Governance for the energy transition. International Journal of Environmental Technology and Management Special issue on: transforming energy systems towards sustainability: critical issues from a socio-technical perspective.

Loorbach, D., Rotmans, J., 2010. The practice of transition management: examples and lessons from four distinct cases. Futures 42, 237–246.

Ludwig, D., Hillborn, R., Walters, C., 1993. Uncertainty, resource exploitation, and conservation: lessons from history. Science 260, 17–36.

Marshall, N.A., 2007. Can policy perception inuence social resilience to policy change? Fisheries Research 86, 216–227.

Marshall, N.A., 2010. Understanding social resilience to climate variability in primary enterprises and industries. Global Environmental Change 20, 36–43.

Marshall, N.A., Fenton, D.M., Marshall, P.A., Sutton, S., 2007. How resource-dependency can influence social resilience within a primary resource industry. Rural Sociology 72, 359–390.

Marshall, N.A., Gordon, I.J., Ash, A.J., 2011. The reluctance of resource-users to adopt seasonal climate forecasts that can enhance their resilience to climate variability. Climatic Change, doi:10.1007/s10584-010-9962-y.

Martens, P., Rotmans, J., 2005. Transitions in a globalizing world. Futures 37, 1133–1144.

Meinke, H., Howden, S.M., Struik, P.C., Nelson, R., Rodriguez, D., Chapman, S.C., 2009. Adaptation science for agriculture and natural resources management–urgency and theoretical basis. Environmental Sustainability 1, 69–76.

Nelson, D.R., Adger, W.N., Brown, K., 2007. Adaptation to environmental change: contributions of a resilience framework. Annual Review of Environment and Resources 32, 395–419.

Orlove, B., 2005. Human adaptation to climate change: a review of three historical cases and some general perspectives. Environmental Science and Policy 8, 589–600.

Osbahr, H., Twyman, C., Adger, W.N., Thomas, D.S.G., 2008. Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. Geoforum 39, 1951–1964.

Österblom, H., Gardmark, A., Bergström, L., Müller-Karulis, B., Folke, C., Lindegrenf, M., Casini, M., Olsson, P., Diekmann, R., Blenckner, T., Humborg, C., Möllmann, C., 2010. Making the ecosystem approach operational – can regime shifts in ecological- and governance systems facilitate the transition? Marine Policy 34, 1290–1299.

Olsson, P. Agency and Leadership Strategies for Innovation and Transformation of Social–ecological Systems, in press.

Olsson, P., Gunderson, L.H., Carpenter, S.R., Ryan, P., Lebel, L., Folke, C., Holling, C.S., 2006. Shooting the rapids: navigating transitions to adaptive. Insight, special feature: exploring resilience in social–ecological systems, governance of social–ecological systems. Ecology and Society 11, 18., In: http://www.ecologyandsociety.org/vol11/iss1/art18/.

Park, S.E., Howden, S.M., Crimp, S. Informing regional level policy development and actions for increased adaptive capacity in rural livelihoods. Environmental Science and Policy, in press.

Parto, S., Loorbach, D., Lansink, A., Kemp, R., 2006. Transitions and institutional change: the case of the Dutch waste subsystem. In: Parto, S.H.-C. (Ed.), Industrial Innovation and Environmental Regulation. United Nations University Press, New York.

Pearson, L.J., Nelson, R., Crimp, S., Langridge, J., 2011. Interpretive review of conceptual frameworks and research models that inform Australia's agricultural vulnerability to climate change. Environmental Modelling and Software 26, 113–123.

Petrie, P., Sadras, V., 2008. Advancement of grapevine maturity in Australia between 1993 and 2006: putative causes, magnitude of trends and viticultural consequences. Australian Journal of Grape and Wine Research 14, 33–45.

Prigogine, I., Stengers, I., 1984. Order Out of Chaos: Men's New Dialogue with Nature. Bantam Books, New York.

Rotmans, J., Loorbach, D., 2009. Complexity and transition management. Journal of Industrial Ecology 13, 184–196.

Rotmans, J., Kemp, R., van Asselt, M.B.A., 2000. Transitions and Transition Management, the Case of an Emission-free Energy Supply. International Centre for Integrative Studies, Maastricht, The Netherlands.

Rotmans, J., Kemp, R., van Asselt, M., Geels, F., Verbong, G., Molendijk, K., 2001. Transitions and Transition Management: The Case for a Low Emission Energy Supply. ICIS, Maastricht, The Netherlands.

Sarewitz, D., Pielke Jr., R.A., 2007. The neglected heart of science policy: reconciling supply of and demand for science. Environmental Science and Policy 10, 5–16.

Schneider, S.H., 2004. Abrupt non-linear climate change, irreversibility and surprise. Global Environmental Change Part A 14, 245–258.

Schultz, H.R., Stoll, M., 2010. Some critical issues in environmental physiology of grapevines: future challenges and current limitations. Australian Journal of Grape and Wine Research 16, 4–24.

Smithers, J., Smit, B., 1997. Human adaptation to climatic variability and change. Global Environmental Change 7, 129–146.

Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Global Environmental Change 16, 282–292.

Stafford Smith, M., Abel, N., Walker, B., Chapin III, F.S., 2009. Drylands: coping with uncertainty, thresholds, and changes in states. In: Chapin, III, F.S., Kofinas, G.P., Folke, C. (Eds.), Principles of Ecosystem Stewardship. Springer, New York, pp. 171–195.

Stafford Smith, M., Horrocks, L., Harvey, A., Hamilton, C., 2011. Rethinking adaptation for a 4 °C world. Philosophical Transactions of the Royal Society A 369, 196–216.

Stokes, C.J., Howden, S.M., 2010. Adapting Agriculture to Climate Change: Preparing Australian Agriculture, Forestry and Fisheries for the Future. CSIRO Publishing, Melbourne.

Tabara, J.D., Ilhan, A., 2008. Culture as trigger for sustainability transition in the water domain: the case of the Spanish water policy and the Ebro river basin. Regional Environmental Change 8, 59–71.

Turner II, B.L., 2010. Vulnerability and resilience: coalescing or paralleling approaches for sustainability science? Global Environmental Change 20, 570–576.

Urwina, K., Jordan, J., 2008. Does public policy support or undermine climate change adaptation? Exploring policy interplay across different scales of governance. Global Environmental Change 18, 180–191.

van der Brugge, R., Rotmans, J., 2007. Towards transition management of European water resources. Water Resource Management 21, 249–267.

van de Kerkhof, M., Wieczorek, A., 2005. Learning and stakeholder participation in transition processes towards sustainability: methodological considerations. Technological Forecasting and Social Change 72, 733–747.

Verweij, M., Thompson, M., 2006. Clumsy Solutions for a Complex World. Palgrave Macmillan, New York.

Walker, B., Holling, C.S., Carpenter, S.R., Kinzig, A., 2004. Resilience, adaptability and transformability in social–ecological systems. Ecology and Society 9 (9) http://www.ecologyandsociety.org/vol9/iss2/art5; <Go to ISI>://000228062200010.

Webb, L., Dunn, G.M., Barlow, E.W.R., 2008. Modelling the relationship between climate, winegrape price and winegrape quality in Australia. Climate Research 36, 89–98.

Webb, L., Dunn, G.M., Barlow, E.W.R., 2010. Winegrapes. In: Stokes, C., Howden, M. (Eds.), Preparing Australian Agriculture, Forestry and Fisheries for the Future. CSIRO Publishing, pp. 101–118.

Wheaton, E.E., Maciver, D.C., 1999. A framework and key questions for adapting to climate variability and change. Mitigation and Adaptation Strategies for Global Change 4, 215–225.

Please cite this article in press as: Park, S.E., et al., Informing adaptation responses to climate change through theories of transformation. Global Environ. Change (2011), doi:10.1016/j.gloenvcha.2011.10.003